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# Abiotic and Biotic stress in livestock production system

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Human population is expected to increase from 7.2 to 9.6 billion by 2050 (UN, 2013). This represents a population increase of 33%, but as the global standard of living increases, demand for agricultural and animal products will increase by about 70% in the same period (FAO, 2009). The livestock sector is a pillar of the global food system and a contributor to poverty reduction, food security and agricultural development. According to the FAO, livestock contributes 40% of the global value of agricultural output and supports the livelihoods and food and nutrition security of almost 1.3 billion people. At the same time, there is wide scope to improve livestock sector practices so that they are more sustainable, more equitable, and pose less risk to animal and human health (FAO, 2021).

Animals have to endure many stressors in their natural environments. They can be categorized as biotic and abiotic stress. For example, they experience food shortages, dwell in areas where predator or parasite densities are high, engage in conflicts with neighbors or group members, and face fluctuations in food and water availability and temperature. Although individuals can often predict when stressors will occur (e.g., more stressors generally in winter than summer), predictions about the intensity or duration of individual stressors are generally not possible (e.g., a failed predation attempt). Consequently, most species have evolved both constitutive and inducible mechanisms for coping with stressors (McEwen & Wingfield 2003).

Abiotic stress is the negative impact of non-living factors on living organisms in a specific environment1. Examples of abiotic stress in animals include Drought, Starvation, Heat, Cold shocks, and other oxidative challenges. These stresses are the major challenges for production of crops, livestock, fisheries, and other commodities. Only 9% of the world's agricultural area is conducive for crop production, while 91% is under stresses which widely occur in combinations. While losses to an



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extent of more than 50% of agricultural production occur due to abiotic stresses, their intensity and adverse impact are likely to amplify manifold with climate change and over exploitation of natural resources. Fragile agroecosystems like the dryland areas are highly vulnerable to such disastrous impact. To mitigate the effects/impact of multiple stressors, proposed strategies include improved agronomic management, while the breeding of stress tolerant genotypes can enhance capacity for adaptation to stress environments. However, a holistic integrated multidisciplinary approach in systems perspectives is a need of the hour to get the best combination of technologies for a particular agroecosystem.

**Abiotic Stress in Animal Production System**

Climate change is seen as a major threat to the survival of many species and ecosystems, and the sustainability of livestock production systems in many parts of the world. On the one hand, the current trend for the demand of livestock products is increasing, which offers market opportunities for small, marginal and landless farmers, while on the other hand, livestock production is facing the negative implications of environmental change, where abiotic stress is noteworthy.

**Temperature**

All animals have a thermal comfort zone, which is a range of ambient environmental temperatures that are beneficial to physiological functions (FAO, 1986). During the day, livestock keep a body temperature within a range of ±0.5 C (Henry et al., 2012). When temperature deviates more than the critical temperature of the range (varies by species type), the animals begin to suffer from stress (FAO, 1986).

**Cold stress:** According to Robert and Gilbert reported that cold stress during periods of inclement weather is largely a problem for free stall-housed dairy cattle that must increase energy intake to maintain body heat. In this instance, thyroid hormones may increase to enhance dry-matter intake. However, regardless of exact pathophysiology, reproductive performance is diminished. Cows are reluctant to interact, tend to lose weight, may suffer production losses as more energy is directed toward body heat and do not like to move about on icy floors and hard irregular surfaces created by frozen manure on floors. Roughened hair coats and losses in body condition are observed in many animals in cold-stressed herds. Heat detection and conception suffer. A more energy-dense ration may need to be formulated when herds suffer from cold stress-induced fertility problems, metabolic problems or production losses.

**Heat Stress:**

In conventional livestock husbandry systems with insulated buildings, mechanical ventilation systems



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and high stocking density pigs and poultry can be more affected by climate change than in free range husbandry systems. Animals have developed a phenotypic response to a single source of stress such as heat called acclimation (Fregley, 1996). Acclimation results in reduced feed intake, increased water intake, and altered physiological functions such as reproductive and productive efficiency and a change in respiration rate (Lacetera et al., 2003; Nardone et al., 2010). Heat stress on livestock is dependent on temperature, humidity, species, genetic potential, life stage, and nutritional status. Livestock in higher latitudes will be more affected by the increase of temperatures than livestock located in lower latitudes, because livestock in lower latitudes are usually better adapted to high temperatures and droughts (Thornton et al., 2009). Confined livestock production systems that have more control over climate exposure will be less affected by climate change (Rotter and van de Geijn, 1999). Heat stress decreases forage intake, milk production, the efficiency of feed conversion, and performance (Haun, 1997; McDowell, 1968; Wyman et al., 1962). Warm and humid conditions cause heat stress, which affects behavior and metabolic variations on livestock or even mortality. Heat stress impacts on livestock can be categorized into feed nutrient utilization, feed intake, animal production, reproduction, health, and mortality.

Livestock have several nutrient requirements including energy, protein, minerals, and vitamins, which are dependent on the region and type of animal (Thornton et al., 2009). Failure to meet the dietary needs of cattle during heat stress affects metabolic and digestive functions (Mader, 2003). Sodium and potassium deficiencies under heat stress may induce metabolic alkalosis in dairy cattle, increasing respiration rates (Chase, 2012).

High-producing dairy cows generate more metabolic heat than low-producing dairy cows. Therefore, high-producing dairy cows are more sensitive to heat stress. Consequently, when metabolic heat production increases in conjunction with heat stress, milk production declines (Berman, 2005; Kadzere et al., 2002). Heat stress also affects ewe, goat, and buffalo milk production (Finocchiaro et al., 2005; Nardone et al., 2010; Olsson and Dahlborn, 1989). The poultry industry may also be compromised by low production at temperatures higher than 30 C (Esminger et al., 1990). Heat stress on birds will reduce body weight gain, feed intake and carcass weight, and protein and muscle calorie content (Tankson et al., 2001). Heat stress on hens will reduce reproduction efficiency and consequently egg production because of reduced feed intake and interruption of ovulation (Nardone et al., 2010; Novero et al., 1991). Egg quality, such as egg weight and shell weight and thickness may also be negatively affected under hotter conditions (Mashaly et al., 2004).

Reproduction efficiency of both livestock sexes may be affected by heat stress. In cows and


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pigs, it affects oocyte growth and quality (Barati et al., 2008; Ronchi et al., 2001), impairment of embryo development, and pregnancy rate (Hansen, 2007; Nardone et al., 2010; Wolfenson et al., 2000). Cow fertility may be compromised by increased energy deficits and heat stress (De Rensis and Scaramuzzi, 2003; King et al., 2006). Heat stress has also been associated with lower sperm concentration and quality in bulls, pigs, and poultry (Karaca et al., 2002; Kunavongkrita et al., 2005)

Prolonged high temperature may affect metabolic rate (Webster, 1991), endocrine status (Johnson, 1980), oxidative status (Bernabucci et al., 2002), glucose, protein and lipid metabolism, liver functionality (reduced cholesterol and albumin) (Bernabucci et al., 2006; Ronchi et al., 1999), non-esterified fatty acids (NEFA) (Ronchi et al., 1999), saliva production, and salivary HCO3 - content.

Warm and humid conditions that cause heat stress can affect livestock mortality. Howden et al. (2008) reported that increases in temperature between 1 and 5 C might induce high mortality in grazing cattle. As a mitigation measure, they recommend sprinklers, shade, or similar management practices to cool the animals.

The potential impacts of temperature on livestock include changes in production and quality of feed crop and forage (Chapman et al., 2012), water availability (Henry et al., 2012), animal growth and milk production (Henry et al., 2012), diseases (Nardone et al., 2010), reproduction (Nardone et al., 2010), and biodiversity (Reynolds et al., 2010). These impacts are primarily due to an increase in temperature and atmospheric carbon dioxide ($CO_2$) concentration, precipitation variation, and a combination of these factors.

**Animal handling and transporting**

One stressor which is easily eliminated is the improper handling of calves by caretakers which can cause both behavioral and physiological stress. Reducing stress during handling will provide advantages of increased health, productivity and even maintaining meat quality. This can sometimes adversely affect reproduction. Transporting animals to a new location has altered oestrus cycles and delayed ovulation, as has constraints and mild shock. These examples illustrate that animal handling techniques that are psychologically disturbing to animals will sometimes adversely affect reproductive efficiency.

**Quantity and quality of feeds**

Quantity and quality of feed will be affected mainly due to an increase in atmospheric $CO_2$ levels and temperature (Chapman et al., 2012). The effects of climate change on quantity and quality of feeds are dependent on location, livestock system, and species (IFAD, 2010). Some of the impacts on feed crops and forage are:


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I. Increase of $CO_2$ concentration will result in herbage growth changes, with greater effect on C3 species and less on grain yields (Chapman et al., 2012). The effects of $CO_2$ will be positive due to inducing partial closure of stomata, reducing transpiration, and improving some plants' water-use efficiency (Rotter and van de Geijn, 1999).

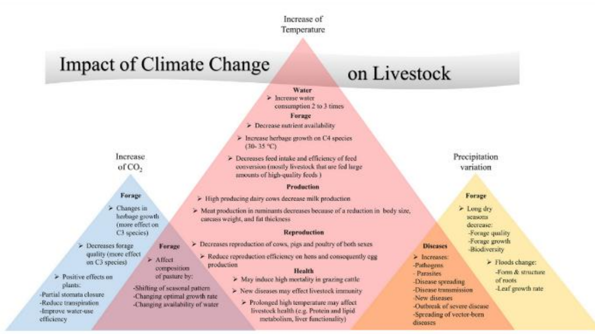
II. C4 species (which account for less than 1% of plants on Earth) are found in warm environments, and have higher water use efficiency than C3 plants. Temperature increases to 30–35 C could increase herbage growth, with larger effects on C4 species. However, the effects may vary depending on the location, production system used, and plant species (Hatfield and Prueger, 2011).

III. Changes in temperature and $CO_2$ levels will affect the composition of pastures by altering the species competition dynamics due to changes in optimal growth rates (IFAD, 2010). Plant competition is influenced by seasonal shifts in water availability (Polley et al., 2013). Primary productivity in pastures may be increased due to changes in species composition if temperature, precipitation, and concurrent nitrogen deposition increase (IPCC, 2007).

IV. Quality of feed crops and forage may be affected by increased temperatures and dry conditions due to variations in concentrations of water-soluble carbohydrates and nitrogen. Temperature increases may increase lignin and cell wall components in plants, which reduce digestibility and degradation rates (Polley et al., 2013), leading to a decrease in nutrient availability for livestock (Thornton et al., 2009). However, as $CO_2$ concentration rises forage quality will improve more in C3 plants than C4 plants. C3 plants also have greater crude protein content and digestibility than C4 plants (Polley et al., 2013).

V. Extreme climate events such as flood, may affect form and structure of roots, change leaf growth rate, and decrease total yield (Baruch and Mérida, 1995).

An increase of $2^0$ C will produce negative impacts on pasture and livestock production in arid and semiarid regions and positive impacts in humid temperate regions. The length of growing season is also an important factor for forage quality and quantity because it determines the duration and periods of available forage.




Source: M.M. Rojas-Downing et al. / Climate Risk Management 16 (2017) 145–163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**Water**

Water availability issues will influence the livestock sector, which uses water for animal drinking, feed crops, and product processes (Thornton et al., 2009). The livestock sector accounts for about 8% of global human water use and an increase in temperature may increase animal water consumption by a factor of two to three (Nardone et al., 2010).

**Biodiversity**

Biodiversity refers to a variety of genes, organisms, and ecosystems found within a specific environment (Swingland, 2001) and contributes to human well-being (MEA, 2005). Populations that are decreasing in genetic biodiversity are at risk, and one of the direct drivers of this biodiversity loss is climate change (UNEP, 2012). Climate change may eliminate 15% to 37% of all species in the world (Thomas et al., 2004). Temperature increases have affected species reproduction, migration, mortality, and distribution (Steinfeld et al., 2006). The Intergovernmental Panel on Climate Change Fifth Assessment Report states that an increase of 2 to 3 C above pre-industrial levels may result in 20 to 30% of biodiversity loss of plants and animals (IPCC,2014)

**Biotic Stress**

Biotic stress is the stress caused by direct and indirect effects of other living organisms such as fungi, bacteria, viruses, nematodes, insects, mites, animals or any biotic factor. A biotic factor is any living component that affects the population of another organism, or the environment. Biotic factors also include human influence, pathogens and disease outbreaks. Biotic stresses emerging out of parasitism and commensalism between microorganisms and higher facultative/obligatory organisms have taken toll in the productivity in the organized sectors for commercial exploitation. Biotic stresses that emanated from intensive animal husbandry practices were primarily due to anomalous use of cross bred cattle which are less resilient to diseases and tropical climate of India compared to our native Zebu breeds. The loss in production of milk, meat and other animal products due to various biotic stresses could be to the tune of 35-46% worth. Global population is estimated to reach 7 billion by 2025 and 10 billion by 2050; also, the climate change scenario will make environment much more hostile for animal productivity than what is experienced today. The demand for nutrition and food of animal origin to human population in the country is expected to rise. In order to keep animal production in pace with increasing demand, at the same time dealing with biotic stress, for sustainable animal husbandry from dwindling resources, needs a well-orchestrated biotic stress management strategy.

**Cause of Biotic Stress**

Diseases causing pathogens are the commonest causes of biotic stress. These



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microorganisms are divided into four Risk Groups (Advisory Committee on Dangerous Pathogens, 1995) representing increasing risks to human and animal health.

**Group 1** have organisms that are unlikely to cause human or animal disease and are disease- producing organisms in animals that are enzootic but not subject to official control. While a non-infectious biological agent may be classified as a hazard group 1 agent, substantial control measures may still be required, as it secrete toxins.

**Group 2** have organisms that may cause human or animal disease but are unlikely to be spread in the community or animal population and for which effective prophylaxis and treatment are available.

**Group 3** have organisms that can cause severe human or animal disease and may spread in the community and/or animal population but for which there is usually effective prophylaxis and treatment.

**Group 4** have organisms that cause severe human or animal disease may represent a high risk of spread in the community or animal population and for which there is usually no effective prophylaxis or treatment.

Evidences also suggest that the climate change will expand the host range of these pathogenic microorganisms, with increased chances of virulent strain development. These organisms are viruses or prions. Therefore, research in biotic stress- tolerance in animals has to be geared up in preparedness for climate change, which is likely to increase the incidence of zoonotic diseases. Assessment of risks caused by an organism and finding out the epidemiological background of the organism, it's infectivity for animals, stability in the environment, ability to infect by different routes of exposure, and susceptibility to specific treatments or prophylaxis, needs to be well documented.

**Interrelations between Abiotic and Biotic factors**

The effects of stress on livestock diseases depend on the geographical region, land use type, disease characteristics, and animal susceptibility (Thornton et al., 2009). Animal health can be affected directly or indirectly by climate change, especially rising temperatures (Nardone et al., 2010). The direct effects are related to the increase of temperature, which increases the potential for morbidity and death. The indirect effects are related to the impacts of climate change on microbial communities (pathogens or parasites), spreading of vector-borne diseases, food-borne diseases, host resistance, and feed and water scarcity (Nardone et al., 2010; Thornton et al., 2009; Tubiello et al., 2008).

Temperature increases could accelerate the growth of pathogens and/or parasites that live part of their life cycle outside of their host, which negatively affects livestock (Harvell et al., 2002; Karl et al., 2009; Patz et al., 2000). Climate change may induce shifts in disease spreading, outbreaks of severe


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disease, or even introduce new diseases, which may affect livestock that are not usually exposed to these type of diseases (Thornton et al., 2009). Evaluating disease dynamics and livestock adaptation will be important to maintain their resilience. Global warming and changes in precipitation affect the quantity and spread of vector-borne pests such as flies, ticks, and mosquitoes (Thornton et al., 2009). In addition, disease transmission between hosts will be more likely to happen in warmer conditions (Thornton et al., 2009). For example, White et al. (2003) simulated the impacts of climate change on Australian livestock, finding that livestock lost about 18% of their weight due to increased tick infestations. Wittmann et al. (2001) also used a model to simulate the response of Culicoides imicola in Iberia, which is the main vector of the bluetongue virus that affects mainly sheep and sometimes cattle, goat, and deer. They reported that the vector would spread extensively with a 2 C increase in global mean temperature. However, these predicted spreads may be prevented by disease surveillance and technologies, such as DNA fingerprinting, genome sequencing, tests for understanding resistance, antiviral medications, cross-breeding, and more (Perry and Sones, 2009; Thornton, 2010). Meanwhile, there is high probability that emergence of new diseases may act as a mixing vessel between human and livestock, facilitating combination of new genetic material and their transmissibility. This makes it difficult to estimate actual disease risk because of the dependence of diseases on animal exposure and interactions factors, (Randolph, 2008).

It has been reported by many workers that various stressors increase the susceptibility to infection. Under stress conditions, pathogens like viruses or mycoplasma predispose the animals to secondarily bacterial infections, allowing opportunistic bacteria to become pathogenic. Increased risk of fatal bacterial respiratory infections following a primary viral infection has been observed in a wide variety of species (25). Viral–bacterial synergy has been established following human influenza epidemics and secondary bacterial respiratory infections leading to increased mortality. Stressors such as transportation have been associated with susceptibility to bovine respiratory diseases (BRD). The most intensively explored relationship of this kind has been that of exposure of calves to weaning and transportation and their subsequent susceptibility to shipping fever. BRD can be caused by a primary infection with a virus, commonly bovine herpesvirus-1 (BHV-1), followed by a secondary bacterial infection with Mannheimia haemolytica (26). The relationship between stress and mastitis in cattle is well documented. Infection by Mycobacteria, causative agent of tuberculosis is known to be increased by stress. Nutritional imbalances, deficiencies can create various types of metabolic diseases like acetonemia, pregnancy toxemia of cattle and sheep on deficient diets, hypocalcemia of sheep, hypomagnesemia of cattle. The sensitivity of animals to the environmental stress is greatest at times


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when they are already affected by metabolic stresses, late pregnancy, lactation etc. Three closely related stress syndromes occur in pigs. The porcine stress syndrome is common in commercial breeds of pigs used to raise low fat pork. It is characterized by acute death induced by stressors such as transport, high ambient temperature, exercise and fighting which lead to hyperthermia, dyspnoea, disseminate vasoconstriction and rapid onset of rigor mortis.

**Need for Biotic Stress Management:** Biotic stress causing losses due to mortality and morbidity have a major impact on the profitability of the livestock operation. Infections – regardless of their severity – will exercise a tax on the nutritional status and reduce nutrients available for productive functions. Recent stimulating papers, show that biotic stress can trigger a transgenerational epigenetic response in plants, where DNA methylation seems to play a central role and this could very well happen in animals too. The evidence that the immune system has critical implication in the major physiological events in the animal's life, especially at high levels of production, could be well exploited to significantly decrease, biotic stress by improved management and nutrition. Feed additives like direct fed microbials, yeast cell wall components, can effectively stimulate the GIT immune modifying the microbial population, ulvans (polysaccharides from green algae), carrageenans and agar (polysaccharides from red algae), exert immunomodulating properties by activating expression of some cytokines and chemokines involved in innate and adaptative immune response. Also feed containing herbs of medicinal importance boosts immune system to positively affect the overall growth and resistance to biotic stress in animals.

The emerging issues on biosafety and biosecurity in animal husbandry, particularly in the light of emerging and re- emerging new diseases as well as possible introduction of exotic organisms to a region could bear economic burden on Indian agriculture. Animal diseases that enter through world-trade corridors as well as through porous/vulnerable land-locked borders have been threatful to the agricultural biosecurity of the country. Biosafety is connoted for various contexts of hazard-perception on animal biodiversity, risks on environment, animal and human health. So, the risk assessment of agro-chemicals, Living modified organisms (LMOs) and other technological products and scientific tools should me mandatory.

**Measures to be Taken**

Futuristic research in the management on emerging new pathogens could address certain aspects of agricultural biosecurity of the country. Certain biological agents like bacteria, virus, fungi, parasites etc., which can be cause of biotic stress can enter environment when conducting laboratory animal experiment. Biosafety programs reduce or eliminate exposure of individuals and the



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environment to potentially hazardous biological agents. Biosafety can be achieved by implementing various degrees of laboratory control and containment, through laboratory design and access restrictions, personnel expertise and training, use of containment equipment, and safe methods of managing infectious materials in a laboratory setting. In the animal industry, the term biosecurity relates to the protection of an animal colony from microbial contamination. They should based upon risk assessment and management methodology; personnel expertise and responsibility; control and accountability for research materials including microorganisms and culture stocks; access control elements; material transfer documentation; training; emergency planning; and program management.

Indian agriculture is spread across more than fourteen agro-climatic regions and under each there are several sub- regions that have typical weather patterns and edaphic factors that influence the biotic factors causing stress. For examples, certain areas are endemic for some nematodes and cestodes infesting ruminants, fly vectors for parasites and viruses, ticks, mites and mosquitoes etc, as a carrier for some pathogens. In fact, these arthropod vectors are themselves a cause of biotic stress to livestock as their biting causes discomfort to animals. Therefore, biotic stress management strategies should be area centric, keeping in view the agro-climatic conditions of the particular region.

It is a fact that still farmers from remote parts of the country are unable to use various modern tools to manage biotic stress in their animals, which creates more pressure to sustainability of resource poor, less knowledgeable farmers. Farmers need to be trained in all possible manners to save his livestock from diseases due to biotic factors. Accessibility of tools and products of animal health management should be increased.

**Mechanism to counter the stress effects:**

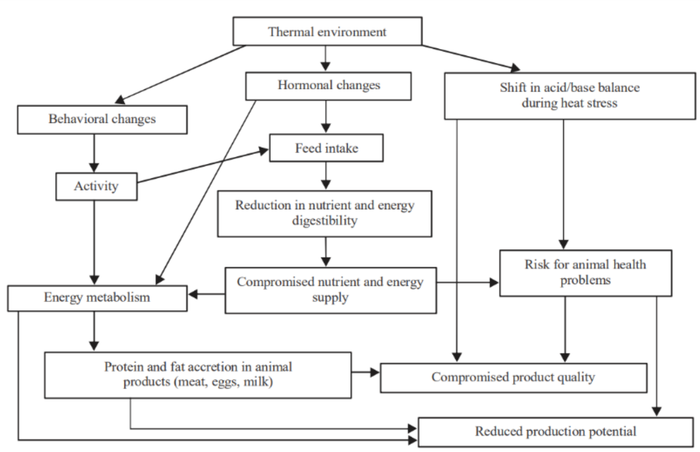


Fig. 1: Potential mode of action of inconvenient thermal environment on the production potential and product quality


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For animals, heat stress is the most stressful among all the abiotic stressors. Reducing the impact of abiotic stress on livestock requires a multidisciplinary approach with emphasis on nutrition, housing and health. Some biotechnological options (designer feeds and forages) may also be used to reduce abiotic stress. It is important to understand the livestock responses to environment and to analyse them carefully in order to alter nutritional and environment-related management practices. To address water scarcity issue, there is a need to produce crops and raise animals in livestock systems that demand less water (Nardone et al., 2010) or in locations with water is in abundance.

In vertebrates, an important mechanism for coping with stressors begins with adrenally-derived glucocorticoid hormones: corticosterone in amphibians, reptiles, and birds, or cortisol in fish and many mammals. These molecules drive gluconeogenesis, suppress reproductive processes, alter movement and feeding rates, impact immune functions, and generally help an individual enter a "state of emergency" when an environmental stressor induces their release (Wingfield et al. 1998). As with urbanization, few data exist on the impacts of introduced species on stress hormone-associated disease in native species. Only one study has reported that the presence of an introduced species impacted glucocorticoid regulation in a native species (Berger et al. 2007).

The study of interactions between stress hormones and immune functions is still a young field, yet research is critical for enhancing our knowledge of disease-coping mechanisms in wild animals, especially in light of escalating anthropogenic changes to the biosphere. Indeed, climate change, non-native species introductions, pollutant exposure, and habitat alterations — especially urbanization — all have the potential to alter stress responses and cause disease (Martin et al. 2010).

**Conclusion**

Commercial animal husbandry has to sustain the stress factors to offer profitability. Scientific tools and techniques would ease the stress endured by livestock and shall provide better initiatives amongst entrepreneurial initiative to continue with productive animal husbandry practice. Ventures and investments in animal farming shall shoot up if mitigation of stresses is contained and reduce the loss of animal products to acceptable levels. Funding and management of research in the areas of managing stresses in animal husbandry is mandatory to enhance sustainable and responsible animal production based on the animal's well- being as a primary consideration.

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